Noise Floor Jamming Equipment on Airplanes

Sean Haynberg, Director of RF Technologies

David Stern, Vice President

Dominic Villecco, President

August 11, 2005

TABLE OF CONTENTS

I. Introduction & Summary

V-COMM, L.L.C. has prepared this report in response to the Commission's request for reply comments in the Cellular Airborne Notice of Proposed Rule Making (*Cellular Airborne NPRM*),[1, 2] regarding the use of cellular and PCS spectrum for airborne handset and aircraft pico cell applications. This report analyzes the technical issues associated with the use of noise floor jamming equipment to effectively prevent airborne handsets from accessing terrestrial signals in flight and operating at maximum power levels.

In preparation for this report, V-COMM reviewed the comments and test data submitted in the Cellular Airborne NPRM comment proceeding, analyzed in-cabin received terrestrial signal levels, in-cabin link budgets required for acceptable service, and the required noise jamming power levels to effectively block or prevent cellular and PCS airborne handsets from accessing and placing terrestrial calls in flight.

Airborne handsets that are *not controlled* by the onboard pico cell and are able to place calls with the terrestrial networks at maximum power (i.e. +30 dBm) have the greatest potential to cause harmful interference to terrestrial networks and aircraft electronic equipment. Therefore, the potential for harmful interference caused by airborne handsets that are not controlled by the onboard pico cell must be considered. This report provides an analysis of the technical issues involved in using noise floor jamming equipment to effectively prevent airborne handsets from acquiring terrestrial signals in flight and transmitting at maximum power levels.[3]

As indicated in this report, very high jamming power levels are required to effectively block all terrestrial calls in flight, i.e. +35 dBm EIRP for cellular band and +20 dBm EIRP for PCS band, for the case above 10,000 feet. Therefore, using jamming equipment alone cannot be the complete solution to providing onboard pico cell service and would cause detrimental harmful interference to CMRS customers' handsets operating on the ground, and also can potentially interfere with aircraft electronic equipment. Therefore, the use of these jamming power levels should not be considered in aircraft pico cell systems, and any proposals to use noise floor jamming equipment must be carefully studied and tested in detail to fully understand the potential harmful interference caused by the use of these systems.

---

[1] The FCC *Cellular Airborne NPRM (NPRM)*, released on Feb 15, 2005, is referenced to the Commission's *Amendment of the Commission's Rules to Facilitate the Use of Cellular Telephones and other Wireless Devices Aboard Airborne Aircraft* (WT Docket 04-435).

[2] V-COMM, L.L.C, is a wireless telecommunications consulting company with principal members having over 20 years experience in the wireless industry. We have provided our expertise to wireless operators in RF engineering, system design, implementation, performance, optimization, and evaluation of new wireless technologies. We have extensive industry experience in all CMRS technologies. V-COMM's company information and experiences are highlighted in this report's Appendix A, along with biographies of senior members of its engineering team. V-COMM has prepared this report pursuant to a contract with Verizon Wireless and Cingular Wireless.

[3] It should be noted that current FCC rules and regulations do not permit the use of noise floor jamming equipment for airborne operation or in ground networks. This report analyzes the technical issues involved with such use predicated on the hypothetical case of such equipment being permited by the FCC and FAA authorities for in-flight use, as proposed by some parties in the instant comment proceeding.

In addition, it is noted that jamming at lower power levels will not be effective in controlling all handsets and preventing terrestrial calls in flight at maximum power levels. Aircraft systems using other methods (i.e. RF window shielding, coordination of frequencies between ground and aircraft systems) in conjunction with lower level jamming may be effective in controlling all handsets on board, however these proposals need to be evaluated and thoroughly tested to ensure harmful interference is not caused to terrestrial networks.

For pico cell operation below 10,000 feet, the noise floor jamming equipment needs to operate at even higher power levels to be effective, or about 10 dB stronger than the jamming power levels required for the above 10,000 feet case. Therefore, noise floor jamming applications below 10,000 feet are even more troublesome and should be avoided to prevent significant harmful interference to terrestrial networks.

To be effective in blocking all terrestrial calls in-flight, noise floor jamming equipment will need to transmit on all forward-link channels used to setup calls (i.e. control channels) in the terrestrial systems. This will require jamming all the active CDMA channels and GSM BCCH channels used in the terrestrial system. Similarly, the channels used to setup calls for UMTS and iDEN terrestrial networks must also be blocked in flight, to prevent these handsets from operating in flight at maximum power levels as well.

Lastly, as examined in two examples in this report, to overcome the jamming signals and provide acceptable pico cell service to CDMA and GSM handsets in the cabin, the onboard pico cells will need to transmit at about the same level as the jamming signals. These hypothetical examples considers aircraft cabin systems with onboard pico cell and noise floor jamming signals utilizing the same patch antenna for transmissions and have the same link budget to all handsets in the airplane cabin.

II. Using Noise Floor Jamming Equipment to Prevent Airborne Handsets from Accessing Terrestrial Signals and Operating at Maximum Power

This section analyzes the technical issues involved in using noise floor jamming equipment to effectively block or prevent airborne handsets from acquiring terrestrial signals in flight and making terrestrial calls at maximum power.[4] Airborne handsets that are *not controlled* by the onboard pico cell will communicate with terrestrial networks at maximum power (i.e. +30 dBm), and have the greatest potential to cause harmful interference to terrestrial networks and aircraft electronic equipment.[5]

Included is an examination of the in-cabin received terrestrial signal levels and the in-cabin link budgets required for acceptable pico cell service, and estimates the required noise jamming power levels to effectively block airborne terrestrial calls in the aircraft cabin.

As indicated below, the use of noise floor jamming equipment to block terrestrial calls in flight will not be effective as a complete solution and has the potential to cause significant forward-link interference to cellular and PCS customer handsets on the ground. Therefore careful consideration is required for any proposals to use noise floor jamming equipment, as well as a detailed review of the in-cabin network design and other possible technical solutions such as aircraft cabin shielding, to determine whether such solutions will be effective in blocking terrestrial calls in flight. In these cases, licensed carriers should be involved in providing such services to ensure ground networks are fully protected from harmful interference.

A. Difficulties in Using Jamming Equipment to Block Terrestrial Calls In-Flight

As illustrated in the next section, the difficulties in using noise floor jamming equipment are due to the high jamming power levels required to effectively block all terrestrial calls, and the potential to cause significant harmful interference to the terrestrial networks (and possibly aircraft electronic equipment) at these high jamming power levels. Low level jamming will not be effective in preventing all airborne handsets from placing calls on the terrestrial networks, and therefore will result in some airborne handsets operating at maximum power levels in flight.[6]

Thus, there are no levels of jamming that will be effective in preventing terrestrial calls in flight while not interfering with ground CMRS networks. Therefore, any aircraft pico cell deployment

---

[4] As indicated on page 19 of V-COMM's technical report submitted in the instant comment proceeding, terrestrial calls can be placed in flight even when onboard pico cells signals are present, due to the handset's system search algorithm that instructs handsets to first access home and preferred system signals from the terrestrial networks, before searching for and using signals from other systems such as onboard pico cell systems.

[5] If onboard pico cells do not control *all* airborne handsets, the handsets will most likely be operating at or near its maximum power level (i.e. +30 dBm), due to the increased distances from the serving terrestrial sites. At these times, the airborne handset will transmit at much higher power levels (i.e. 1,000 times stronger than a handset at 0 dBm) and can cause significant harm to thousands of terrestrial sites along its flight path that are sharing the same spectrum.

[6] Airborne handsets operating at maximum power levels have the potential to cause significant harmful interference to terrestrial base stations, and to aircraft electronic equipment.

will require additional measures to be effective, such as using window shielding to attenuate the terrestrial signals in the cabin to prevent airborne calls from being placed on the terrestrial networks at maximum power levels.

Aircraft window shielding has the potential to improve the airborne system in two ways: 1.) it reduces the terrestrial signals received at CMRS handsets in the cabin, and thus requiring lower jamming power levels to block such terrestrial calls in flight, and 2.) it reduces the jamming signal leakage from the aircraft toward the ground networks. Therefore the application of window shielding can be further studied to assess the benefits of this application,[7] however this option also has the drawback of reducing the terrestrial signals in the cabin when the airplane is on the ground, which may prevent terrestrial calls from being placed when inside aircraft taxing and at airport gates.

Therefore, for any proposed aircraft systems and solutions, careful system design and testing must be performed to ensure the onboard pico cell system does not cause interference to ground cellular and PCS networks.

B. Jamming Power Levels Required to Block Terrestrial Calls In-Flight

This section provides a detailed examination of the in-cabin received terrestrial signal levels and the in-cabin link budgets required for acceptable pico cell service, and estimates the required noise jamming power levels to effectively block airborne terrestrial calls in the aircraft cabin. The measurement data that was provided and submitted by Qualcomm in the instant comment proceeding was used for this analysis, which were acquired from its in-flight measurements on CDMA handset receivers and in-cabin propagation studies conducted within airplanes on the ground. Therefore, this analysis focuses on the jamming power levels that are necessary to prevent CDMA terrestrial calls in flight. In addition, a similar analysis is performed for GSM and UMTS handsets as indicated below assuming that similar terrestrial signal level ranges will be received in the cabin for these technologies as well.[8]

To effectively block terrestrial calls in flight the onboard jamming signal must transmit at power levels that are sufficiently strong to disrupt the reception and acquisition of terrestrial signals in the aircraft cabin. The required jamming power level depends on: 1.) the received terrestrial signal levels; 2.) the link budget from the jamming equipment’s transmit antenna to the handsets in the cabin; and 3.) the ratio of received jamming levels to terrestrial signal levels required to prevent CMRS calls.

[7] The additional attenuation provided by the window shielding may be on the order of 10 to 30 dB depending on the RF shielding materials and implementation.
[8] This assumes that GSM and UMTS base stations utilize similar output power levels to serve the same markets as CDMA base stations.

Received Terrestrial Signal Levels in the Aircraft Cabin

The in-flight measurement data collected by Qualcomm and submitted in the instant comment proceeding was used for this analysis. The terrestrial CDMA signals were collected on CDMA handset receivers in the aircraft cabin for altitudes above 10,000 feet and below 10,000 feet.[9]

For the case above 10,000 feet, the terrestrial CDMA signals are received as high as -60 dBm in the cellular band, and as high as -75 dBm in PCS band. The 90th percentile received terrestrial signals are -65 dBm for the cellular band and -81 dBm for the PCS band.

For the case below 10,000 feet, the terrestrial CDMA signals are received as high as -50 dBm in the cellular band, and as high as -63 dBm in PCS band. The 90th percentile received terrestrial signals are -55 dBm for the cellular band and -70 dBm for the PCS band.

These received terrestrial signal levels are used in the analysis below to assess the jamming levels that are needed to block terrestrial calls in flight.

Ratio of Jamming to Terrestrial Signals Required to Prevent CMRS Calls

To prevent airborne CDMA handsets from placing terrestrial calls in flight, the received jamming signals need to be stronger than the received terrestrial signals by the ratio of the jamming to terrestrial signal level as outlined below.

For CDMA handsets in the aircraft cabin, the jamming signal must be received 15 dB stronger than terrestrial signals received to prevent all CDMA calls from being placed in flight. The 15 dB ratio is required to attenuate strong CDMA received pilot Ec/Io as high as -5 dB to the pilot Ec/Io of -20 dB, which is required to prevent CDMA calls.[10] Qualcomm's in-flight measurements show received pilot Ec/Io up to -5 dB for handsets in "idle mode". It also measured the "idle mode" pilot Ec/Io of -8 dB as the 90% level above 10,000 feet in PCS band. It should be noted that CDMA handsets in the "active mode" can receive pilot Ec/Io values up to 3 dB stronger than "idle mode" pilot Ec/Io values, due to the CDMA idle mode handoff algorithm.[11] Thus, the strongest received pilot Ec/Io level of -5 dB is used in this analysis, and requires jamming signals to be 15 dB stronger than the received terrestrial signals.

In-flight measurement data for UMTS and GSM terrestrial signals were not available and are not included in this analysis, however it can be noted that these technologies may require about the same jamming signals to terrestrial signal ratios to prevent terrestrial calls. For example, to prevent UMTS calls the required jamming signals may need to be about 20 dB stronger than the

[9] The in-flight measurements of terrestrial CDMA signals were collected by Qualcomm and submitted in its comments in this proceeding (see figures 1& 2 on page 4 of its comments). These results are labeled as the CDF of measured forward link power per CDMA channel for the Cellular and PCS bands.

[10] Qualcomm also notes in its comments (pg 8, footnote 2) that "in order to prevent successful pilot demodulation an Ec/Io value of -20 dB should be considered at the design goal."

[11] In addition, the strongest pilot Ec/Io may not always be on the handset's neighbor list (typically limited to 20 pilots), particularly for airborne measurements that have line-of-sight propagation conditions to hundreds of cell sites, and therefore any airborne measurements using the neighbor list for searching pilots will not necessary measure the strongest pilot Ec/Io values.

received terrestrial UMTS signals[12] (versus CDMA calls that require 15 dB stronger jammer signals to block CDMA calls), however the jamming power per MHz level and jamming power spectral density for CDMA and UMTS calls are the same.[13] These levels are required to prevent successful demodulation of CDMA & UMTS calls operating with Ec/Io up to -5 dB. To prevent GSM calls from occurring in flight, jammers would need to disrupt the minimum C/I tolerable for successful GSM calls (i.e. C/I of 6 dB for a very poor quality GSM call), and be received at about 5 dB below the terrestrial signals.[14] Thus, the required noise jamming level for GSM airborne handsets is about 12 dB below the CDMA handset requirement.[15]

Received Jamming Levels Required to Block Terrestrial Calls

To prevent airborne handsets from placing terrestrial calls in flight, the received jamming signal levels need to be stronger than the received terrestrial signal levels by the ratio of the jamming to terrestrial signal levels required to prevent CMRS calls.

Using the values provided above for this ratio and the received terrestrial signals for the above 10,000 feet case, the jamming signal must be received at –60 dBm at PCS handsets, and –45 dBm at Cellular handsets to be effective in controlling all CDMA handsets in the cabin.[16]

For pico cell operation below 10,000 feet, the noise floor jamming signal needs to be received at higher levels to be effective, or about 10 dB stronger than the jammer level required for the above 10,000 feet case. To be effective in controlling 90% of the CDMA handsets below 10,000 feet, the jamming signals need to be received at –55 dBm at PCS handsets, and –40 dBm at Cellular handsets. And, to control 100% of CDMA handsets below 10,000 feet, the jamming signals need to be received at –48 dBm at PCS handsets, and –35 dBm at Cellular handsets.

In-Cabin Link Budget

Using the link budget provided in Qualcomm's Comments for the in-cabin network design, the total allowable path loss & fade margin is 82.7 dB.[17] Qualcomm assumes a link budget of 82.7 dB is required for two sector deployments to provide coverage to the entire aircraft, which

[12] UMTS technology employs about 3 times the bandwidth as CDMA technology, has about 5 dB more processing gain, and can operate at Ec/Io levels that are about 5 dB lower than CDMA technology. Therefore, UMTS technology will require jamming signals that are 20 dB stronger than the received terrestrial UMTS signals (in the UMTS 3.84 MHz receiver bandwidth).

[13] The jamming power level requirements are the same for CDMA and UMTS after adjusting for the differences in the bandwidth of the two signals (i.e. 5 dB for 3 times the bandwidth).

[14] For example, with a required C/I of 5 dB to prevent GSM calls, the jammer signal would need to be received 5 dB below the terrestrial GSM signal received at the GSM handset in the cabin. The bandwidth of both signals is 200 kHz for this case.

[15] CDMA handsets require jamming signals that are received 15 dB stronger than terrestrial CDMA signals in a 1.25 MHz bandwidth, and GSM handsets require jamming signals received 5 dB below the received terrestrial GSM signals in a 200 kHz bandwidth. Adjusting for the bandwidth differences (8 dB for 1.25 MHz vs. 200 kHz) the noise jamming signal for CDMA needs to be 12 dB stronger than the GSM case.

[16] To be effective in controlling 90% of the CDMA airborne handsets above 10,000 feet jamming signals need to be received at –66 dBm at PCS handsets, and –50 dBm at Cellular handsets.

[17] In Section V, In-Cabin Network Design, of Qualcomm Comments, pages 20-21.

assumes a path loss of 62.7 dB and fade margin of 20 dB for the in-cabin network. For one-sector deployments, the same link budget is assumed to provide coverage to about 12 meters of the aircraft cabin. The in-cabin fade margin of 20 dB is required to account for multipath fades, which occur from both patch antennas and leaky coax. Therefore, it is assumed for this analysis that a minimum required in-cabin link budget is 80 dB, from the transmit patch antenna to cellular and PCS handsets in the cabin seats. The link budget of 80 dB is used in the analysis below to estimate the required jamming transmit power levels.

Jamming Transmit Power Levels Required to Block Terrestrial Calls

The jamming transmit power levels required to effectively block terrestrial calls in flight are based on the required received jamming levels and the in-cabin link budget as outlined above. Using these values, the noise floor jamming equipment is required to transmit at about +20 dBm (100 mW EIRP) in the PCS band and +35 dBm (3.2 W EIRP) in the cellular band to be effective in preventing all terrestrial CDMA calls in flight for altitudes above 10,000 feet.[18, 19]

For pico cell operation below 10,000 feet, the noise floor jamming equipment needs to operate at even higher power levels to be effective, or about 10 dB stronger than the jammer level required for the above 10,000 feet case. To be effective in controlling 90% of the CDMA handsets below 10,000 feet, the jamming signal needs to transmit at +25 dBm (316 mW EIRP) in PCS and +40 dBm (10W EIRP) in Cellular bands. And, to control 100% of CDMA handsets below 10,000 feet, the jamming signal needs to transmit at +32 dBm (1.6 W EIRP) in PCS and +45 dBm (31 W EIRP) in Cellular bands within the aircraft cabin.

This analysis assumes no window shielding is used. Using aircraft window shielding in combination with noise floor jamming equipment can reduce the required jamming power levels for the in cabin network. The amount of attenuation and isolation provided by window shielding techniques needs to be studied to determine the effectiveness of using these applications for onboard pico cell systems.

Therefore, due to the very high jamming power levels required to effectively block all terrestrial calls in flight (i.e. +35 dBm for cellular, above 10,000 feet), using jamming equipment alone cannot be the complete solution to providing onboard pico cell service and would cause detrimental harmful interference to CMRS customers' handsets operating on the ground,[20] and

---

[18] Computed as: Jamming Tx Power Req = Jamming Rx Power Req (-60 dBm for PCS and -45 dBm for cellular) + link budget of 80 dB = Jamming Tx of +20 dBm for PCS and +35 dBm for Cellular.

[19] To be effective in controlling 90% of the terrestrial CDMA calls above 10,000 feet jamming signals need to be transmitted at +14 dBm in the PCS band and +30 dBm in the Cellular band.

[20] As indicated in Section 6 on pg 17 of V-COMM's technical report submitted in the instant comment proceeding as an attachment to Cingular and Verizon Wireless' Comments, onboard pico cell forward-link power levels need to operate about the same power levels as airborne handsets to prevent interference to handsets on the ground. Also, see page 14 for the required power limits for airborne handsets to prevent interference to ground networks, for the case with two handsets transmitting above 10,000 feet, which is the transmit power level of -15 dBm EIRP for cellular and -8 dBm EIRP for the PCS band. Therefore, the jammer power levels indicated above (i.e. +35 dBm EIRP for cellular, +20 dBm EIRP for PCS, for the case above 10,000 feet) are significantly higher (i.e. 28 higher for PCS and 50 dB higher for Cellular) than the operating levels required to prevent interference to handsets on the ground networks.

also can potentially interfere with aircraft electronic equipment. Therefore, the use of these jamming power levels should not be considered in aircraft pico cell systems, and any proposals to use noise floor jamming equipment must be carefully studied and tested in detail to fully understand the potential harmful interference caused by the use of these systems.

C. All Terrestrial Forward-Link Control Channels Need to be Blocked In-Flight

In order for jamming equipment to block all terrestrial calls in-flight all forward-link channels used to setup calls (i.e. control channels) in the terrestrial systems will need to be blocked in the aircraft. For example, these channels include all the CDMA channels used in the terrestrial system for setting up calls such as the forward-link paging channels in both the cellular and PCS bands. This will most likely require jamming of all the active CDMA channels used in the terrestrial system.[21] For GSM terrestrial systems, these channels include all the GSM broadcast control channels (i.e. forward-link BCCH channels) used in the terrestrial system for setting up calls, in both the cellular and PCS spectrum. This may require jamming of all GSM channels used in the terrestrial system, to ensure all BCCH channels are blocked in-flight.[22] Similarly, the channels used to setup calls for UMTS and iDEN terrestrial networks must also be blocked in flight, to prevent these handsets from operating in flight at maximum power levels.

D. Operating Power Levels for In-Cabin Pico Cells, With Onboard Jammers

To provide acceptable pico cell service to airborne CMRS handsets in the airplane cabin, the onboard pico cells will need to operate at power levels sufficient to close the link for the in-cabin network, and must overcome the power level of the onboard jammers such that the jammer will not interference with pico cell forward-link transmissions to the airborne handsets.

As examined in two hypothetical systems below, to overcome the jamming signals and provide acceptable pico cell service to CDMA and GSM handsets in the cabin, the onboard pico cells will need to transmit at about the same level as the jamming signals. These hypothetical examples considers aircraft cabin systems with onboard pico cell and noise floor jamming signals utilizing the same patch antenna for transmissions and have the same link budget to all handsets in the airplane cabin.[23]

---

[21] These include the forward-link CDMA paging channels used to setup CDMA calls, which are normally used in all active CDMA channels in the terrestrial systems. When CDMA handsets are powered on, they search for their home and preferred systems on the primary or preferred CDMA channels assignments in cellular and PCS spectrum. After this initial search, CDMA handsets operate on the active CDMA channels and are "hashed" or divided among the active channels based on the handset's mobile identification number (MIN) and system hashing algorithm. Therefore, airborne CDMA handsets may operate on any active CDMA channel used in the terrestrial network, and those channels need to be blocked in flight to prevent terrestrial calls on those channels at maximum power.

[22] The BCCH channels are used in terrestrial GSM networks for setting up calls. GSM operators have the flexibility to utilize the GSM BCCH channel in any standard GSM channel in the cellular or PCS band. Therefore, to prevent GSM terrestrial calls in-flight, all BCCH channels used in the GSM terrestrial networks in cellular and PCS spectrum need to be blocked to prevent airborne GSM calls at maximum power.

[23] For any pico cells and jamming systems that use different transmit antennas within the airplane cabin, the independent link budgets and fade margins need to be taken into account to determine appropriate

The following two examples describe the operating pico cell power levels required to provide acceptable airborne service to CDMA and GSM handsets in the aircraft cabin, for aircraft systems that utilize noise floor jamming equipment.

1. Hypothetical Onboard CDMA Pico Cell System Operating With Jammers

To provide acceptable pico cell service to airborne CDMA handsets in the cabin, the onboard CDMA pico cell will need to transmit at about the same level as the jamming signal is transmitting.[24] This will allow the airborne CDMA handsets to receive sufficient signal strength to close the link for acceptable in-cabin service.

In this case, the onboard CDMA pico cell would need to transmit with the maximum traffic channel fraction power per user of greater than 6% (equivalent to 12 dB below the maximum transmit power for the pico cell). This will allow CDMA handsets in the cabin to operate with received traffic channel Ec/Io of greater than -15 dB for quality airborne CDMA calls.[25]

Also, in other cases, the onboard CDMA pico cell may be able to transmit at lower power levels than the jamming signal. For example, with pico cells transmitting with maximum traffic channel fraction power per user of 20% (equivalent to 7 dB below the total transmitted maximum power for the pico cell), the onboard CDMA pico cell total transmit power level can operate as low as 7 dB below the jamming transmit signal level. This assumes the jammer and the pico cell total power signals will add approximately 1 dB to the total received noise level at the airborne CDMA handsets due to the differences in operating levels, and will allow airborne CDMA handsets to receive traffic channel Ec/Io of greater than -15 dB for quality airborne CDMA calls.

2. Hypothetical Onboard GSM Pico Cell System Operating With Jammers

To provide acceptable pico cell service to airborne GSM handsets in the cabin, the onboard GSM pico cell will need to transmit at sufficient power levels to close the link for acceptable in-cabin service. This output power level needs to be about the same power level as the jamming signal is transmitting, and the bandwidth of the two signals need to be considered as described below.[26]

---

operating levels for the onboard pico cells. Such systems that use difference antennas for transmissions are not studied in this report.

[24] This output power level for the onboard CDMA pico cell is the composite power level of the CDMA carrier consisting of the necessary channels to serve onboard CDMA handsets, which include the system's forward-link pilot, paging, sync, and traffic channels.

[25] This case assumes the total transmitted power of the pico cell and the jammer are approximately the same, and that both signals will add 3 dB to the total received noise level at the CDMA handsets in the cabin.

[26] Also, in some cases the onboard GSM pico cell may be able to transmit at lower power levels than the jamming signal if narrowband notch filters are used in series with the jamming signals to reduce the operating noise level on specific GSM 200 kHz channels. However, in these cases, the onboard GSM pico cells must transmit on the filtered GSM channels at sufficient levels to block terrestrial GSM signals that can be acquired in flight.

To determine the operating power level for the GSM pico cell case, we need to review the received jamming level at the airborne GSM handsets. GSM handsets will receive jamming signals 8 dB lower in signal strength as compared to CDMA handsets, due to the differences in receiver bandwidth (200 kHz vs. 1.25 MHz). Therefore, assuming a C/I of 9 dB is required for quality airborne GSM calls, onboard pico cells need to transmit on GSM 200 kHz channels at levels that are approximately 1 dB above the level of a jamming signal power reference to a 1.25 MHz bandwidth, or approximately 9 dB above a jamming signal power referenced to a 200 kHz bandwidth.[27] This will allow GSM handsets in the cabin to operate with sufficient operating margins for acceptable airborne service.

III. Conclusion

Due to the very high jamming power levels required to effectively block all terrestrial calls in flight, i.e. +35 dBm for cellular and +20 dBm for PCS for the case above 10,000 feet, using jamming equipment alone cannot be the complete solution to providing onboard pico cell service and would cause detrimental harmful interference to CMRS customers' handsets operating on the ground, and also can potentially interfere with aircraft electronic equipment. Therefore, the use of these jamming power levels should not be considered in aircraft pico cell systems, and any proposals to use noise floor jamming equipment must be carefully studied and tested in detail to fully understand the potential harmful interference caused by the use of these systems.

Jamming at power levels below these amounts will not be effective in controlling all handsets and preventing terrestrial calls in flight at maximum power levels. Aircraft systems using other methods (i.e. RF window shielding, coordination of frequencies between ground and aircraft systems) in conjunction with lower level jamming may be effective in controlling all handsets on board, however these proposals need to be evaluated and thoroughly tested to ensure harmful interference is not caused to terrestrial networks.

For pico cell operation below 10,000 feet, the noise floor jamming equipment needs to operate at even higher power levels to be effective, or about 10 dB stronger than the jamming power levels required for the above 10,000 feet case. Therefore, noise floor jamming applications below 10,000 feet are even more troublesome and should be avoided to prevent significant harmful interference to terrestrial networks.

To be effective in blocking all terrestrial calls in-flight, noise floor jamming equipment will need to transmit on all forward-link channels used to setup calls (i.e. control channels) in the terrestrial systems. This will require jamming all the active CDMA channels and GSM BCCH channels used in the terrestrial system. Similarly, the channels used to setup calls for UMTS and iDEN terrestrial networks must also be blocked in flight, to prevent these handsets from operating in flight at maximum power levels as well.

In addition, as examined in two examples in this report, to overcome the jamming signals and provide acceptable pico cell service to CDMA and GSM handsets in the cabin, the onboard pico

[27] For example, for a wide-band jamming equipment with a transmit power level of +20 dBm/1.25MHz, the pico cell would need to operate with a CDMA maximum transmit power of +20 dBm/1.25MHz and a GSM pico cell transmit power level of approximately +21 dBm/200kHz.

cells will need to transmit at about the same level as the jamming signals. These hypothetical examples considers aircraft cabin systems with onboard pico cell and noise floor jamming signals utilizing the same patch antenna for transmissions and have the same link budget to all handsets in the airplane cabin.

Appendix A – Company Information & Biographies

V-COMM is a leading provider of quality engineering and engineering related services to the worldwide wireless telecommunications industry. V-COMM's engineering staff is experienced in Cellular, Personal Communications Services (PCS), Enhanced Specialized Mobile Radio (ESMR), Paging, Wireless Data, Microwave, Signaling System 7, and Local Exchange Switching Networks. We have provided our expertise to wireless operators in engineering, system design, implementation, performance, optimization, and evaluation of new wireless technologies. Further, V-COMM was selected by the FCC & Department of Justice to provide expert analysis and testimony in the NextWave and Pocket Communications Bankruptcy cases. V-COMM has offices in Blue Bell, PA and Cranbury, NJ and provides services to both domestic and international markets. For additional information, please visit V-COMM's web site at www.vcomm-eng.com.

BIOGRAPHIES OF SENIOR MEMBERS OF V-COMM, L.L.C.

Dominic C. Villecco
President and Founder

Dominic Villecco, President and founder of V-COMM, is a pioneer in wireless telecommunications engineering, with 22 years of executive-level experience and various engineering management positions. Under his leadership, V-COMM has grown from a start-up venture in 1996 to a highly respected full-service consulting telecommunications engineering firm.

In managing V-COMM's growth, Mr. Villecco has overseen expansion of the company's portfolio of consulting services, which today include a full range of RF & Network design, engineering & support; network design tools; measurement hardware; and software services; as well as time-critical engineering-related services such as business planning, zoning hearing expert witness testimony, regulatory advisory assistance, and project management.

Before forming V-COMM, Mr. Villecco spent 10 years with Comcast Corporation, where he held management positions of increasing responsibility, his last being Vice President of Wireless Engineering for Comcast International Holdings, Inc. Focusing on the international marketplace, Mr. Villecco helped develop various technical and business requirements for directing Comcast's worldwide wireless venture utilizing current and emerging technologies (GSM, PCN, ESMR, paging, etc.).

Previously he was Vice President of Engineering and Operations for Comcast Cellular Communications, Inc. His responsibilities included overall system design, construction and operation, capital budget preparation and execution, interconnection negotiations, vendor contract negotiations, major account interface, new product implementation, and cellular market acquisition. Following Comcast's acquisition of Metrophone, Mr. Villecco successfully merged the two technical departments and managed the combined department of 140 engineers and support personnel.

Mr. Villecco served as Director of Engineering for American Cellular Network Corporation (AMCELL), where he managed all system implementation and engineering design issues. He was responsible for activating the first cellular system in the world utilizing proprietary automatic call delivery software between independent carriers in Wilmington, Delaware. He also had responsibility for filing all FCC and FAA applications for AMCELL before it was acquired by Comcast.

Prior to joining AMCELL, Mr. Villecco worked as a staff engineer at Sherman and Beverage (S&B), a broadcast consulting firm. He designed FM radio station broadcasting systems and studio-transmitter link systems, performed AM field studies and interference analysis and TV interference analysis, and helped build a sophisticated six-tower arrangement for a AM antenna phasing system. He also designed and wrote software to perform FM radio station allocations pursuant to FCC Rules Part 73.

Mr. Villecco started his career in telecommunications engineering as a wireless engineering consultant at Jubon Engineering, where he was responsible for the design of cellular systems, both domestic and international, radio paging systems, microwave radio systems, two-way radio systems, microwave multipoint distribution systems, and simulcast radio link systems, including the drafting of all FCC and FAA applications for these systems.

Mr. Villecco has a BSEE from Drexel University, in Philadelphia, and is an active member of IEEE. Mr. Villecco also serves as an active member of the Advisory Council to the Drexel University Electrical and Computer Engineering (ECE) Department.

Relevant Expert Witness Testimony Experience:

Over the past five years, Mr. Villecco had been previously qualified and provided expert witness testimony in the states of New Jersey, Pennsylvania, Delaware and Michigan. Mr. Villecco has also provided expert witness testimony in the following cases:

- United States Bankruptcy Court

- NextWave Personal Communications, Inc. vs. Federal Communications Commission (FCC) **

- Pocket Communications, Inc. vs. Federal Communications Commission (FCC) **

** In these cases, Mr. Villecco was retained by the FCC and the Department of Justice as a technical expert on their behalf, pertaining to matters of wireless network design, optimization and operation.

David K. Stern
Vice President and Co-Founder

David Stern, Vice President and co-founder of V-COMM, has over 20 years of hands-on operational and business experience in telecommunications engineering. He began his career with Motorola, where he developed an in-depth knowledge of wireless engineering and all the latest technologies such as CDMA, TDMA, and GSM, as well as AMPS and Nextel's iDEN.

While at V-COMM, Mr. Stern oversaw the design and implementation of several major Wireless markets in the Northeast United States, including Omnipoint - New York, Verizon Wireless, Unitel Cellular, Alabama Wireless, PCS One and Conestoga Wireless. In his position as Vice President, he has testified at a number of Zoning and Planning Boards in Pennsylvania, New Jersey and Michigan.

Prior to joining V-COMM, Mr. Stern spent seven years with Comcast Cellular Communications, Inc., where he held several engineering management positions. As Director of Strategic Projects, he was responsible for all technical aspects of Comcast's wireless data business, including implementation of the CDPD Cellular Packet Data network. He also was responsible for bringing into commercial service the Cellular Data Gateway, a circuit switched data solution.

Also, Mr. Stern was the Director of Wireless System Engineering, charged with evaluating new digital technologies, including TDMA and CDMA, for possible adoption. He represented Comcast on several industry committees pertaining to CDMA digital cellular technology and served on the Technology Committee of a wireless company on behalf of Comcast. He helped to direct Comcast's participation in the A- and B-block PCS auctions and won high praise for his recommendations regarding the company's technology deployment in the PCS markets.

At the beginning of his tenure with Comcast, Mr. Stern was Director of Engineering at Comcast, managing a staff of 40 technical personnel. He had overall responsibility for a network that included 250 cell sites, three MTSOs, four Motorola EMX-2500 switches, IS-41 connections, SS-7 interconnection to NACN, and a fiber optic and microwave "disaster-resistant" interconnect network.

Mr. Stern began his career at Motorola as a Cellular Systems Engineer, where he developed his skills in RF engineering, frequency planning, and site acquisition activities. His promotion to Program Manager-Northeast for the rapidly growing New York, New Jersey, and Philadelphia markets gave him the responsibility for coordinating all activities and communications with Motorola's cellular infrastructure customers. He directed contract preparations, equipment orders and deliveries, project implementation schedules, and engineering support services.

Mr. Stern earned a BSEE from the University of Illinois, in Urbana, and is a member of IEEE.

Sean Haynberg
Director of RF Technologies

Sean Haynberg, Director of RF Technologies at V-COMM, has over 15 years of experience in wireless engineering. Mr. Haynberg has extensive experience in wireless system design, implementation, testing and optimization for wireless systems utilizing CDMA, TDMA, GSM, AMPS and NAMPS wireless technologies. In his career, he has conducted numerous first office applications, compatibility & interference studies, and new technology evaluations to assess, develop and integrate new technologies that meet industry and FCC guidelines. His career began with Bell Atlantic NYNEX Mobile, where he developed an in-depth knowledge of wireless engineering.

While at V-COMM, Mr. Haynberg was responsible for the performance of RF engineering team supplying total RF services to a diverse client group. Projects varied from managing a team of RF Engineers to design and implement new a PCS wireless network in the NY MTA; to the wireless system design & expansion of international markets in Brazil and Bermuda; to system performance testing and optimization for numerous markets in the north and southeast; to the development and procurement of hardware and software engineering tools; to special technology evaluations, system compatibility and interference testing. He has also developed tools and procedures to assist carriers in meeting compliance with FCC rules & regulations for RF Safety, and other FCC regulatory issues. In addition, Mr. Haynberg was instrumental in providing leadership, technical analysis, engineering expertise, and management of a team of RF Engineers to deliver expert-level engineering analysis & reporting on behalf of the FCC & Department of Justice, in the NextWave and Pocket Communications Bankruptcy proceedings.

Prior to joining V-COMM, Mr. Haynberg held various management and engineering positions at Bell Atlantic NYNEX Mobile (BANM). He was responsible for evaluating new technologies and providing support for the development, integration and implementation of first office applications (FOA), including CDMA, CDPD, and RF Fingerprinting Technology. Beyond this, Haynberg provided RF engineering guidelines and recommendations to the company's regional network operations, supported the deployment and integration of new wireless equipment and technologies, including indoor wireless PBX/office systems, phased/narrow-array smart antenna systems, interference and inter-modulation analysis and measurement, and cell site co-location and acceptance procedures. He was responsible for the procurement, development and support of engineering tools for RF, network and system performance engineers to enhance the system performance, network design and optimization of the regional cellular networks. He began his career as an RF Engineer responsible for the system design and expansion of over 100 cell sites for the cellular markets in New Jersey, Philadelphia, PA; Pittsburgh, PA; Washington, DC; and Baltimore, MD market areas.

Mr. Haynberg earned a Bachelor of Science degree in Electrical Engineering with high honors, and attended post-graduate work, at Rutgers University in Piscataway, New Jersey. While at Rutgers, Mr. Haynberg received numerous honors including membership in the National Engineering Honor Societies Tau Beta Pi and Eta Kappa Nu. In addition, Mr. Haynberg has qualified and provided expert witness testimony in the subject matter of RF engineering and the operation of wireless network systems for many municipalities in the State of New Jersey.